beginning with *Endoceras, Gyroceras, Phragmoceras* and others characteristic of the Silurian merging into the more elaborate and coiled *Goniatites, Nautilus* and *Orthoceratites* of the Carboniferous, and into these forms and the *Ammonites* in the Cretaceous. The latter appear in great elegance and profusion from the Lias. In this and the two succeeding ages in which this family reached its maximum the Ammonite and Nautilus group are represented by a number of genera. The series closes in the multiplicity of Cretaceous forms *Ancyloceras, Crioceras, Scaphites, Hamites, Toxoceras* and many others. A heavy slab covered with Trigonia is noticeable among the Lamellibranchs. But a mere enumeration of these series and other Invertebrates that have not been mentioned gives but an inadequate impression of their value as a typical collection, which rests so largely, not upon their number but upon their exceptional perfection and completeness.

From New Zealand are the recent struthious birds, the collection containing many incomplete skeletons of *Meinornis, Dinornis* and *Palapteryx*, and completing the series are three fine Moas, one of them standing 8 feet high. There are important remains of *Halitherium, Titanotherium* and *Rhinoceros*, the latter from the Black Hills. From the Pleistocene shell marl underlying the peat beds near Limerick is a tall Irish elk, *Megaceros Hibernicus*, quite rare in this country. A cave bear from the south of France is one of the most perfect specimens that has been found. It is mounted complete, the ribs and a few vertebræ alone having been restored. These, with a large mastodon from Hudson, N. Y., a skull of Bos Primigenius, and many scattered Mammalian remains give an admirable idea of the Post Pliocene fauna of Europe and America.

The east wing of the museum is almost entirely filled by the collection. It contains no plaster, but the originals of over 130 of Ward's series of casts. It reflects the greatest credit upon the intelligence and energy of its collector. It will come into immediate service in connection with a lately instituted course of lectures upon Palæontology, and give new impetus to the general interest in Biology at Princeton.

## THE CLASSIFICATION OF SCIENCE.

REV. SAMUEL FLEMING, LL. D., PH. D.

II.

### PRINCIPLES OF CLASSIFICATION.

Science may be properly classified with respect to either the order and facts of nature, or the laws of thought and methods of obtaining the knowledge of facts. In respect to the first basis, the classification may proceed upon the twofold method of arranging the order and laws of phenomena, separately considered, or of considering these in their immediate connection. And while either special method involves the complex process of nature, which is the province of philosophy in the discovery of laws,—the object of classification is to set forth the order of facts and laws which have already been discovered. It is a statement of their connections as brought within the scope of observation, as they stand in their completeness of order, while many facts may still remain unknown. Processes are continually going on in the physical realm, as exhibited in the heavens and in the earth. It is hence not a statement of historical development of each particular science, nor of the body of sciences. It is not an arrangement according to the chronological order of discovery of the facts. It is not a curriculum or course of study for discipline and acquisition. Such a course is arranged with reference to a harmonious development of mind, and requires the prosecution of diverse studies pursued simultaneously. Yet a proper classification proceeds upon the method of arranging or grouping the subordinate sciences according to both the order of philosophic inquiry, and of the subordination of facts and principles to the divisions and uses of science from the lower to the higher, and from phenomena to laws and applications.

Further, any scheme of clasification, founded upon material existences and relations irrespective of the immaterial entities which give qualities and motion to the material, must be radically defective. The fact of an order of succession in respect to the modification of the primary Force which inheres in matter, is too obvious to need more than a statement of the fact. Thus, in organic existence, the all-related force of Gravity is *general*, being applied to all bodies, whatever their constituents or mode of combination, while modified forms of this principle are limited to specializations. As at every step in the gradation of material existences, the order of nature is from the inorganic to the organic, so these terms involve the general and the special, and the addition proceeds from the lower and more general forms of force to the higher, more limited and special. Thus, also, in organic being we find Life as a common or general substance or entity, forming the basis of the general division of science denominated Biology. The lowest specialized form of life pertains to Botany,—the science of organic unconscious vegetal life, including many classes; the next higher pertains to Zoology, which is the science of that form of organic life, which has consciousness and animation, including many classes, and subordinate orders, kinds and species. The highest in gradation of being pertains to Anthropology, the science of the form of organic life which is conscious and rational, limited to mankind. In every higher order a new capacity has been added. It has been a "life unto life."

This natural order of classification from generals to specials, and from the lower to the higher, may be illustrated by the following diagrams, commencing with the lower, or gravitation, as in reading the scheme of classification accompanying this paper:

Life, { Man=organization+sensation+rational mind. / Animal=organization+consciousness and sensation. / Plant=organization. }

Force, { Special: Chemical affinity. / Special: Cohesion. / General: Gravitation. }

The fundamental distinctions of this classification are those which pertain to the body of sciences included in the scheme given. They are first, *Ontology*, the science of being, or the material or immaterial substances, qualities and attributes of universal being. This properly includes not only the general divisions given, but those which relate to the superior orders of being not given, viz.: Angeology, Christology and Theology. A classification of all Science, therefore, embraces these subjects. Ontology includes three general divisions: Cosmology, Biology and Anthropology. These are arranged in their natural order, as based upon the succession of immaterial or spiritual entities united with their respective material forms. Such order is essentially *serial*: in other words, there is a gradation of existences, as just noticed, and as indicated by the branch and group-descriptive terms given in the body of the scheme, as *Physico-dynamic*, etc.

Each general division includes its subordinate divisions or departments. Cosmology, the science of inorganic nature, includes three departments: Physical, Mechanical and Chemical Philosophy. The general term, Dynamology, formed upon the Greek etymon *dunam*, is used to designate the science of the immaterial principle, Force, as Biology designates the science of the vital principle, or Life. Biology and Anthropology include the several branches or departments as given. Individuals of a group are allied by some mode, principle or law distinguishing them from others in special respects.

The progress of science within the past few decades, and the very wide applications rendering divisions of scientific research and use indispensable, has made it necessary more and more to distinguish the several subordinate branches of a general division with reference to special relations and purposes of science. What has been denominated physical science in the reeent past is found to include too extensive a field of culture and use, and to require too vast an amount of scientific labor in research, analysis and application, both for individual gratification and for the demands of science. Then "Natural Philosophy" monopolized the whole field. Now Chemical Philosophy has taken the rank of a distinct department, and has extended its domain in every direction wherever it could find a field of research. It has even been obliged to review its own analyses, and to criticise its own results, by further experiment upon its own elements, to determine whether they are themselves compounds. And the analyses have yielded important fruits. Recently four new elements—cæsium, rubidium, thallium and iridium--have been detected by the new and wonderful method of the Spectrum Analysis, a notice of which will be given farther onward.

But Mechanical philosophy has an equal claim to distinction as a special department. Its aims and uses are practical--the relations and applications of matter and motion to mechanical effects; and in this age of inventive genius and of vastly extended applications of mechanical force to the demands of utility, give increasing importance to this department of science. The distinguishing triumphs of the past few years have resulted from the conservation of those forces and agencies which appear phenomenally in their general relations in physical nature, but are now specialized in this department for the higher uses of human society. Thus the form of force which has operated naturally as heat in all the previous history of matter, has become a science in mechanical philosophy, manipulated and controlled by scientific art, and takes the name of Thermotics, a science of vast extent and application. Hydrology has become specialized in Hydro-dynamics, Aerology in Pneumatics, Electricity in Electro-magnetism, etc. The subdivision of Physico-dynamic science into three departments--Physics, Mechanics and Chemics--seems to be demanded by the vastly extended range and special applications of these, as well as by the legitimate distinction recognized between *phenomena* and *laws*.

Cosmogony is treated as a branch of Astronomy. It is obvious this is its place, from the fact that Stellar Astronomy grows out of it, and includes its forming masses and nebular states. This contemplates a prior state, and the processes of the formation of special masses from the original mass of nebulous matter. The advancement from nebulous masses to globes in the various stages of condensation gives Stellar Astronomy. The sun is one of the stars, and is specialized as the center of the system to which our planet belongs, and hence Solar Astronomy is a consequent, and its place above Stellar Astronomy is appropriate. Again; our earth, far back in the periods of world-formations, was in its cosmogenic stage, forming part of the great nebulous cosmos; hence the term *geogony*, the science of the genesis of the earth, is grouped with *cosmogony*. But while the greater part of the earth's interior is still in its gaseous state, the facts pertaining to its crust create a new sub-group, as Geology, Mineralogy and Seismology.

Biology is divided into two general departments, while it includes three sub-sciences, viz.: Botany or Phytology, Zoology and Anthroposophy,—the latter being the science of the human physiological constitution. The radical distinction between animals and man pertains chiefly to the immaterial nature—the latter possessing rational and moral capacities, and also an order of physical nature not possessed by animals; yet a real distinction obtains physiologically, and indeed a vastly greater difference than between any of the different orders of animals. This distinction is stated in the classification. Physiology, which pertains to man's physical nature, is the subscience of Biology, termed Anthroposophy, while comparative physiology, and morphology, belong respectively to Zoology and Phytology—the former relating to beings having sentient but irrational life, and the latter to insentient or unconscious life.

If this method of division, in which Biology and Anthropology share in the inclusion of a special subject appears to be anomalous, it is legitimate; for while both include those sciences which are grouped as belonging to physiological nature, Anthropology includes also the higher order of psychical nature, in essential connection with our mental, rational and moral nature,—entities and attributes of an imperishable subsistence, but whose functions and development for temporal existence depend upon the physiological connection. Biology is the general science of organic being having *Life;* Botany is the special science of organic being having *vegetal life;* Zoology is the special science of organic being having *sentient* life; Anthroposophy is the special science of organic being having *rational* life—the latter term having been chosen to express the distinction maintained above. If it is held by any readers of this paper that animals possess a psychical nature, as well as man, be it so. At least a nervo-ethereal nature may be predicated of beings having sensation and the power of voluntary motion; and such a substratum or basis of the physical as well as the sentient nature of animals, as corresponds with man's psychical nature, may exist, perhaps must. If so, it is reasonable to presume it must be of an order as much lower than man's psychical nature, as the mental or sentient constitution of animals is lower than man's. But if such psychical nature does exist, the fact can be known only by rational induction, for the beast has no capacity for language to verify the assumption.

### INCOMPLETE, SUBORDINATE AND CONDITIONING SCIENCES.

Few of the physical sciences, especially, can be completly developed by themselves. Physics, Mechanics and Chemics are more or less mutually related, either as conditioned or conditioning. Astronomy has necessarily required for observation of its facts some of the principles and laws of physical optics, while scientific art has been called to construct appropriate instruments for observation, as the telescope and spectroscope. And the laws of planetary and stellar motion must necessarily be known before the science of astronomy can be fully acquired. But classification cannot await the discovery of all the facts of science, but must proceed with the materials at hand, when radical distinctions have been determined.

Geogony treats of general phenomena, the unformed, but forming and mingling elements, and conditions of meteorology by furnishing the materials involved in the latter science, in its special sphere.

Meteorology cannot be completed as a science by the study of the atmosphere alone, but in connection with the facts which reveal themselves by the action of atmospheric electricity. Thermotics, the science of heat, is but partially developed by the study of the ethereal radiations giving the physical phenomena of heat, but finds its completion in the experiments and application of mechanics, of hydrology and pneumatics.

Paleontology, being allied with mineralogy in respect to the general process of stratification, by furnishing materials which enter into it, properly belongs where it is assigned; yet these materials, constituted in part of fossils, cannot be completed without employing the facts which are brought forward in vital organisms. Hence paleontology is given as a conditioning science, contributing to botany and zoology, inasmuch as the ancient organisms, while many of them contain extinct types, are made a study in connection with living organisms;

and thus the apparent anomaly of the same branch of science being grouped both with physics and biology, is explained by the fact that paleontology, in its mere physical relations, deals with substances irrespective of relations to organisms, while fossilogy belongs to both. So, as already noticed, anthroposophy belongs both to biology and anthropology.

Light and sound are grouped together because produced by vibratory motion, yet not affiliated, because the media of vibration differ, the former being ether and the latter air. The analogy between light and sound is illustrated by firing a cannon at a distance from the observer; first the flash of light is seen at the moment of the explosion of the powder, transmitted at the rate of about 184,000 miles per second, the sound being heard some moments after the flash is seen, transmitted at the rate of about 1100 feet per second. Neither the luminous body nor the sonorous body throws off any *substance*, but only gives an impulse in wave-form causing vibrations of different kinds of substance,—ethereal vibrations exciting the optic nerve causing the sensation of seeing, and aerial vibrations exciting the auditory nerves causing the sensation of hearing. But while acoustics (or photology) is grouped with physical optics, in respect to the cause of their production, both musical sounds and colors are grouped as belonging to esthetics high in the series of science. In these respects both phonology and photology are subordinate sciences.

Actinism, produced by vibration of ether, like light, but exceeding in rate those which produce the highest color, *i. e.*, exceeding 800 billions of miles per second, is affiliated with electricity, light and heat, and bears relations to two diverse and widely separated sciences—photography and phytology. Its action is both chemical and vital, operating on the sensitive silver in photography (which more properly may be termed actinography), and also constitutes the vital agency necessary to excite germination in plants. This latter result has been attributed to the violet ray revealed by the spectrum, but this may be owing to the fact that the higher, inconceivably rapid vibrations of ether producing the actinic rays are not appreciated, and the effects in germination have been associated with the highest rays of light brought within the scope of vision. Actinism is hence grouped generally with sound, and specially with heat, light and electricity, but is subordinate to botany. There are reasons for the theory that electricity is concerned in normal vital action—not only vegetal, but animal.

Nature has anticipated both the mechanic and the fine arts. Far down in the depths of mineralogy are found gems of rarest beauty—the esthetics of Architecture. Up in the field of meteorology the clouds are tinted by the sunbeams with a perfection of beauty surpassing the possibilities of the esthetic art of Painting. "The music of the spheres" have for centuries enchanted the votaries of astronomical science, and still challenges the admiration of all observers contemplating the perfection of that grand choral movement which excels the harmony of a Handel or Beethoven—anticipating the rhythm both of Poetry and Music. Mineralogy, meteorology and astronomy belong to physical science, but they have furnished elements of the esthetic forms which reason appropriates in the sphere and achievements of the Fine Arts.

## THE ROTATORY POWER OF COMMERCIAL GLUCOSE.*

### A METHOD OF DETERMINING THE PERCENTAGE OF REDUCING MATTER BY THE POLARISCOPE.

BY H. W. WILEY, Lafayette, Ind.

In the "trade" the name "grape sugar" is applied only to the solid product obtained from starch.

The name "glucose" is given to the thick syrup obtained from the starch, and which is used in immense quantities in this country for table use and other purposes.

Before being sent into the market it is usually mixed with a little cane sugar syrup to give it color rather than flavor, since the glucose itself is quite or nearly colorless. My polariscope is the *holb-schotten* variety, and is used with the sodium monochromatic light. The sugar scale is graduated to give 100 divisions, with a tube 200 m.m. long filled with sugar solution of 26.048 grammes in 100 c.c.

The angular rotation produced is 34°.7, which shows a specific rotatory power of 66°.6 for pure cane sugar.

In all my examinations I took 10 grammes of glucose in 100 c.c., and used tubes of observation 200 m.m. in length.

The average specific gravity of the various glucoses I examined was 1.412, and the number may be taken as a standard.

In order to conform to the followfng formulæ the specific gravity should not vary greatly from this number.

I have found from a large number of observations that the average reading on the sugar scale for 10 grammes of glucose in 100 c.c. is about 50 divisions. When the reading approached 53 divisions I found that the glucose contained nearly 53 per cent. of reducing matter, as determined by Fehling's solution. When the reading fell below 53 the percentage of reducing matter was above 53 and *vice versa*. I therefore made a large number of observations to determine, if possible, any relation between the polariscopic reading and the percentage of reducing matter.

I found as a result that the difference between the polariscopic reading and 53 multiplied by 1.25 gave a product which, added to or subtracted from 53, would give the percentage of reducing matter required. When we consider the difficulty of hitting the exact point in using the copper solution, the differences exhibited in the following table will not seem so important. See following page.

From a study of the following table we may write the following formulæ:

Let $g$ = percentage of reducing substance, and $a$ = reading of polariscope.

We may have three cases:

1st. $a = 53$.
2d. $a > 53$.
3d. $a < 53$.

For case 1st, $g = 53$ per cent.
Case 2d, $g = 53 - (a - 53)\ 1.25$ per cent.
Case 3d, $g = 53 + (53 - a)\ 1.25$ per cent.

ILLUSTRATIONS.

No. 14, following table.

$a = 40$.
$g = 53 + (53 - 40)\ 1.25 = 69.25$ per cent.

No. 16, following table.

$a = 63.80$.
$g = 53 - (63.80 - 53)\ 1.25 = 39.50$ per cent.

In seven of the seventeen cases given the percentage of reducing matter calculated from the polariscope exceeds that given by the copper solution and by a mean amount of .539 per cent. In ten of them it falls short, and by an average of .938.

In many examinations made subsequent to the above the mean deviation has been even less.

Hence I can say that the method indicated will give results which in the mean differ by less than the half of one per cent. from the reduction tests. I regard my calculations from the polariscope equally as reliable as those made with the copper solution.

* Read before the A. A. A. S., Boston, 1880.